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Description

GLOBAL ELECTRONIC TRADING SYSTEM

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Related Applications

This application is related to and claims priority upon U.S. provisional patent application serial number 60/249,796 filed November 17, 2000 and U.S. provisional patent application serial number 60/288,310 filed May 2, 2001, which two provisional patent applications are hereby incorporated by reference in their entireties into the present patent application.

Technical Field

This invention pertains to the field of global electronic trading of commodities and financial instruments.

Background Art

Wright, Ben, "Unlocking the C2C forex riddle", euromoney.com, July 25, 2001, U.K., provides a general discussion of some of the business aspects of the present invention.

Morris, Jennifer, "Forex goes into future shock", Euromoney, October 2001, gives a general description of several computerized foreign exchange platforms, including one described in the present patent application.

1 Ahuja, R.K., Magnanti, T.L., and Orlin, J.B., Network
2 Flows; Theory, Algorithms, and Applications, Chapters 7 and 9
3 (Prentice-Hall, Inc. 1993), U.S.A., sets forth some algorithms
4 that may be useful in implementing the present invention.
5

6 U.S. patent 5,375,055 discloses a relatively simple
7 trading system that is capable of implementing only single-hop
8 trades. On the other hand, the present invention can
9 accommodate multi-hop trades. Further, in U.S. patent
10 5,375,055, the user is given information that suggests to him
11 that he can take a trade when he may not have enough credit to
12 take the whole trade. In the present invention, on the other
13 hand, if only part of a trade can be executed, that
14 information is given to the user; the user knows that he has
15 enough credit to execute at least the best bid and best offer
16 that are displayed on his computer.
17

18 An even simpler trading system is disclosed in European
19 patent application 0 411 748 A2 and in granted European
20 patents 0 399 850 B1 and 0 407 026 B1, all three of which are
21 assigned to Reuters Limited. These Reuters documents describe
22 a system in which information concerning a potential trade is
23 displayed even if the user can't execute it at all. In the
24 present invention, such a potential trade would not be
25 displayed at all. Furthermore, the only credit limits that
26 can be accommodated in the Reuters system are volume limits
27 for the purposes of limiting settlement risk. In the present
28 invention, any agent may set credit limits in multiple ways so

1 as to limit not only settlement risk (measured both by
2 individual instrument volumes and by notional absolute values)
3 but also exposure risk. Furthermore, the Reuters keystations
4 require a human operator. In the present invention, on the
5 other hand, an API (application programming interface) enables
6 any participant to develop programs which partially or fully
7 automate the trading process.
8

9 Disclosure of Invention

10 Methods, systems, and computer readable media for
11 facilitating trading two items (L,Q) from the group of items
12 comprising commodities and financial instruments. At least
13 two agents (2) want to trade some instrument L at some price
14 quoted in terms of another instrument Q. The exchange of L
15 and Q is itself a financial instrument, which is referred to
16 as a traded instrument. A trading channel (3) between the two
17 agents (2) allows for the execution of trades. Associated
18 with each channel (3) are trading limits configured by the two
19 agents (2) in order to limit risk. A central computer (1)
20 coupled to the two agents (2) is adapted to convey to each
21 agent (2) current tradable prices and available volumes for
22 the exchange of L for Q and for the exchange of Q for L,
23 taking into account the channel (3) trading limits. The
24 central computer (1) facilitates trades that occur across a
25 single trading channel (3) and trades that require the
26 utilization of multiple trading channels (3).
27
28

1 Brief Description of the Drawings

2 The file of this patent or application contains at least
3 one drawing executed in color. Copies of this patent or patent
4 application publication with color drawings will be provided
5 by the USPTO upon request and payment of the necessary fee.
6

7 These and other more detailed and specific objects and
8 features of the present invention are more fully disclosed in
9 the following specification, reference being had to the
10 accompanying drawings, in which:

11 Figure 1 is a block diagram illustrating a "type zero"
12 trading system embodiment of the present invention.

13 Figure 2 is a block diagram illustrating a "type 1"
14 trading system embodiment of the present invention.

15 There is no Figure 3.

16 Figure 4 is a block diagram illustrating a "type 2"
17 trading system embodiment of the present invention.

18 Figure 5 is a block diagram illustrating a "type 2" back-
19 to-back trade using the present invention.

20 Figure 6 is a block diagram illustrating an interlocking
21 network of type 1 and type 2 atomic units.

22 Figure 7 is a schematic diagram illustrating trading
23 limits for a traded instrument being traded between four
24 agents 4,5 using three trading channels 3.

25 Figure 8 is a block diagram illustrating various ways
26 that agents 2 can be connected to enable them to use the
27 present invention.
28

1 Figure 9 is a timeline illustrating an embodiment of the
2 matching process used in the present invention.

3 Figure 10 is a block diagram illustrating an embodiment
4 of the border outpost process of the present invention.

5 Figure 11 is a deal fulfillment graph.

6 Figure 12 is a flow diagram illustrating the sequence of
7 screen shots appearing on the computer of an agent 2 using the
8 present invention.

9 Figure 13 illustrates a log-in screen 21 of the computer
10 of an agent 2.

11 Figure 14 illustrates a custom limit order book overview
12 window 24 (multiple traded instruments).

13 Figure 15 illustrates a custom limit order book window 25
14 (single traded instrument).

15 Figure 16 illustrates a net exposure monitor 35.

16 Figure 17 illustrates a balance sheet window 36.

17 Figure 18 illustrates an open order overview and
18 management window 33.

19 Figure 19 illustrates a bid creation dialog box 28.

20 Figure 20 illustrates an offer creation dialog box 29.

21 Figure 21 illustrates a buy (immediate execution bid)
22 dialog box 30.

23 Figure 22 illustrates a sell (immediate execution offer)
24 dialog box 31.

25 Figure 23 is a flow diagram illustrating the computation
26 of a custom limit order book 24,25.

1 Figure 24 is a flow diagram illustrating the computation
2 of multi-hop flow limits for a single traded instrument among
3 all accounts.

4 Figure 25 is a flow diagram illustrating computation of a
5 directed graph of single-hop flow limits for a single traded
6 instrument among all accounts.

7 Figure 26 is a flow diagram illustrating computation of
8 minimum and maximum excursions for a single account A and a
9 single traded instrument.

10 Figure 27 is a flow diagram illustrating computation of a
11 position limit for a lot instrument L.

12 Figure 28 is a flow diagram illustrating computation of a
13 position limit for a quoted instrument Q.

14 Figure 29 is a flow diagram illustrating computation of a
15 volume limit for a lot instrument L.

16 Figure 30 is a flow diagram illustrating computation of a
17 volume limit for a quoted instrument Q.

18 Figure 31 is a flow diagram illustrating computation of a
19 notional position limit.

20 Figure 32 is a flow diagram illustrating computation of a
21 notional volume limit.

22 Figure 33 is a flow diagram illustrating computation of a
23 traded instrument L:Q position limit.

24 Figure 34 is a flow diagram illustrating computation of a
25 traded instrument L:Q volume limit.

1 Figure 35 is a flow diagram illustrating reporting by
2 computer 1 of a single-hop trade.

3 Figure 36 is a flow diagram illustrating reporting by
4 computer 1 of a multi-hop trade.

5
6 Detailed Description of the Preferred Embodiments

7 The present invention enables an arbitrary number of
8 agents 2 of arbitrary type (such as corporate treasuries,
9 hedge funds, mutual funds and other collective investment
10 schemes, banks and other financial institutions, and other
11 institutions or persons) to trade commodities and financial
12 instrument pairs directly amongst each other (thus
13 facilitating client-to-client, or C2C trading) by making
14 orders to their peers to buy and sell the traded instrument
15 pairs over "credit atomic units" and "credit molecules".

16 By way of example, the application highlighted most often
17 herein is the spot foreign exchange (spot FX) market, but it
18 must be understood that the present invention has
19 applicability to trading in any type of over-the-counter
20 commodity or financial instrument, including physical
21 commodities, energy products (oil, gas, electricity),
22 insurance and reinsurance products, debt instruments, other
23 foreign exchange products (swaps), and compound instruments
24 and other derivatives composed or derived from these
25 instruments.
26

27 A trade is the exchange of a lot of instrument L for a
28 quoted instrument Q. The lot instrument L is traded in an

1 integral multiple of a fixed quantity referred to as the lot
2 size. The quoted instrument Q is traded in a quantity
3 determined by the quantity of the lot instrument L and the
4 price. The price is expressed as Q per L. In a spot FX
5 trade, the lot instrument L and the quoted instrument Q are
6 implicit contracts for delivery of a currency on the "spot"
7 date (typically two business days after the trade date).
8

9 In the present specification and claims, entities that
10 wish to trade with each other are referred to as "agents" 2.
11 Agents 2 that extend credit to other agents 2 are referred to
12 as credit-extending agents 5. Agents 2 that do not extend
13 credit to other agents 2 are referred to as clients 4 or non-
14 credit-extending agents 4.

15 Two agents 2 may have direct trading channels 3 between
16 them, where the trading channels 3 correspond to credit
17 extended from one credit-extending agent 5 (typically a bank,
18 financial institution, or any clearing entity) to the other
19 agent 2. Trading channels 3 are typically secured via
20 placement of collateral (margin) or other form of trust by an
21 agent 2 with the credit-extending agent 5. Typically, trading
22 channels 3 amongst credit-extending agents 5 and non-credit-
23 extending agents 4 already exist. In the spot FX market,
24 these trading channels 3 are referred to as trading accounts.
25 In the case that two credit-extending agents 5 have a trading
26 channel 3 between them, only one agent 2 acts in a credit-
27 extending capacity with regards to that trading channel 3.
28

1 Credit-extending agents 5 that allow the central computer
2 1 to utilize a portion of their trading channels 3 to allow
3 other agents 2 to trade with each other are referred to as
4 "credit-bridging agents" 5. In a preferred implementation of
5 the present system, existing banks, financial institutions,
6 and clearing entities are credit-bridging agents 5 as well as
7 credit-extending agents 5; and existing trading customers of
8 those institutions 5 are clients 4.
9

10 Compared with prior art systems, the present invention
11 gives a relative advantage to clients 4 compared to credit-
12 extending agents 5, by enabling one-way or two-way orders from
13 any agent 2 to be instantly displayed to all subscribing
14 agents 2, enabling a trade to take place at a better price,
15 with high likelihood, than the price available to clients 4
16 under prior art systems. The present invention brings
17 together clients 4 who may be naturally on opposing sides of a
18 trade, without conventional spreads historically charged to
19 them 4 by credit-extending agents 5 for their 5 service as
20 middlemen. Of course, credit-extending agents 5 also benefit
21 on occasions when they are natural sellers or buyers.
22

23 Unlike prior art systems, the present invention arranges
24 multi-hop deals to match orders between natural buyers and
25 sellers who need not have a direct trading relationship. For
26 the application to spot FX trading, a multi-hop deal can be
27 realized through real or virtual back-to-back trades by one or
28 more credit-bridging agents 5. In terms of the underlying

1 transfers of financial instruments, a multi-hop deal is
2 similar to the existing practice of trade "give-ups" from one
3 broker to another.

4
5 Unlike prior art systems, the present invention computes
6 trading limits from not only cumulative volume but also from
7 net position limits, where both volume and position limits may
8 be set in terms of the traded instrument (instrument L for
9 instrument Q), in terms of any underlying instruments to be
10 exchanged (delivered) upon settlement (such as L individually,
11 Q individually, or other instruments), or in terms of the
12 notional valuations of such instruments. This allows all
13 agents 2, especially credit-bridging agents 5, to control risk
14 far more flexibly. Limiting traded or delivered instruments'
15 cumulative volume helps to manage settlement risk. Limiting a
16 traded instrument's net position (net L:Q position) helps to
17 manage market risk. Limiting a delivered underlying
18 instrument's net position (total net L, total net Q, or some
19 other underlying instrument's position) helps manage market
20 and credit risk by reflecting the ultimate effect of any trade
21 on any account's future balance sheet. The cumulative volume
22 limits allowed by prior art systems are able to address only
23 settlement risk concerns.

24
25 The present invention has a natural symmetry; in the
26 preferred implementation, not only are credit-bridging agents
27 5 (financial institutions) able to operate as market makers
28 and post one-way (just a bid or ask) and two-way (both bid and

ask) prices to agents 2, but clients 4 may post one-way and two-way prices to credit-bridging agents 5 and other clients 4 of any other credit extending or credit bridging agent 5. This symmetry is not present in prior art trading systems.

The present invention uses a central computer 1 to calculate trading limits, to prepare custom limit order books 24,25, and to match orders, but all post-trade bookkeeping and settlement is handled in a de-centralized manner by the counterparties 2 involved in each trade. The central computer 1 is a network of at least one physical computer acting in a closely coordinated fashion.

Every agent 2 subscribing to a system employing the present invention can be thought of as a node 2 in an undirected graph (Figs. 1-6, 11). The undirected edges 3 of such graphs indicate the existence of a trading channel 3 (account) between two nodes 2, typically an arrangement of trading privileges and limits based on the extension of credit from one node 2 to another 2 and likely backed by collateral placed by one node 2 with the other 2. Some nodes 5 in the graph, corresponding to credit-bridging agents 5, allow credit to be bridged, while other nodes 4 are clients 4 who permanently or temporarily forbid credit bridging. For the application to spot FX trading, a credit-bridging agent 5 authorizes the central computer 1 to initiate back-to-back spot trades, where simultaneous trades in opposite directions at the same price are made between the credit bridging agent 5

1 and two or more different agents 2, such that the net position
2 effect to the credit bridging agent 5 is exactly zero.

3 For each trading channel (account 3), the central
4 computer 1 maintains a set of limits set by the credit-
5 extending agent 5 and a set of limits set by the non-credit-
6 extending agent 2. Either of these sets of limits may be
7 empty. These limits specify maximums of cumulative volume of
8 each traded instrument L:Q, maximum cumulative volume of an
9 underlying instrument (e.g. L, Q, or other), maximum
10 cumulative notional value (e.g. U.S. dollar equivalent),
11 maximum positive or negative net position of each traded
12 instrument L:Q, maximum positive or negative net position of
13 the underlying instrument (e.g. L, Q, or other), and maximum
14 absolute net position notional (e.g., U.S. dollar equivalent)
15 value total.
16

17 For each trading channel (account) 3, the central
18 computer 1 maintains information sufficient to compute the
19 current value of all the quantities upon which limits may be
20 placed. The cumulative volume values are reset to zero with
21 some period, typically one business day, at such a time as is
22 agreeable to both agents. It is illustrative to note that the
23 cumulative volume values always increase toward their limit
24 with each trade, while the net position values may be
25 decreased back to zero or near zero and may change in sign.
26

27 An agent 2 may add, remove, or adjust any of the elements
28 of the set of limits specified by that agent 2 at any time.

1 Since trading is permitted or denied based on these
2 limit-related values, the central computer 1 provides a way
3 for the agents 2 that are parties to an account to inform the
4 central computer 1 of any external activity that would affect
5 these values, such as odd-lot trades and trades made through
6 existing trading devices, or to simply reset all limit-related
7 values to a predefined state.
8

9 Based on the current values of all these limit-related
10 quantities, the central computer 1 computes for each traded
11 instrument L:Q a directed graph (Fig 7) of maximum excursions.
12 In the directed graph for each traded instrument L:Q, each
13 directed edge 3 from a node 2 to another node 2 has a value
14 that indicates, based on the current position, how many of the
15 traded instrument L:Q may be bought by the first node 2 from
16 the second node 2. There are typically directed edges 3 in
17 both directions between any pair of nodes 2, since the
18 instrument L:Q may be bought or sold. The trading limit
19 values (maximum excursions) of these buying and selling edges
20 3 between two nodes 2 vary from moment to moment as trades are
21 made and/or credit limits are adjusted by either node 2.
22

23 For all traded instruments L:Q and for all nodes 2 that
24 trade L:Q and for all other nodes 2 that trade L:Q, the
25 central computer 1 uses the directed graph of maximum
26 excursions (Fig. 7) to compute the maximum flow from the first
27 node 2 to the second node 2. Note that this means that each
28

1 pair of nodes 2 that trade L:Q will have the maximum flow
2 between them 2 calculated in both directions.

3
4 The prior art systems could be simulated by the present
5 invention by first eliminating the ability of any node 2 to be
6 a credit-bridging agent 5 so that the "single-pair maximum
7 flow" is merely the flow enabled by directed edges 3
8 connecting the pair of nodes 2 directly. Second, all trading
9 limits by non-credit-extending agents 4 would be disabled and
10 only cumulative volume limits on underlying instruments would
11 be allowed for credit-extending agents 5, corresponding to
12 limits only on settlement risk.

13 For purposes of illustrating the present invention,
14 consider, for example, an agent A extending credit to agent B
15 for the purposes of trading spot FX using the present
16 invention, and between the U.S. dollar (USD), Euro (EUR), and
17 Japanese Yen (JPY) in particular. Suppose agent B buys 1 lot
18 of EUR:USD at 0.9250, then sells 1 lot of EUR:JPY at 110.25,
19 with both trades having agent A as counterparty 2. The first
20 trade will upon settlement result in 1,000,000 EUR received by
21 agent B and 925,000 USD paid by agent B, while the second
22 trade will result in 1,000,000 EUR paid by agent B and
23 110,250,000 JPY received by agent B. From the perspective of
24 agent B, the account stands +1M EUR toward the EUR:USD
25 cumulative volume limit, +1M EUR toward the EUR:USD net
26 position limit, +1M EUR toward the EUR:JPY cumulative volume
27 limit, -1M EUR toward the EUR:JPY net position limit, +2M EUR
28

1 toward the EUR cumulative volume limit, +925,000 USD toward
2 the USD cumulative volume limit, +110,250,000 JPY toward the
3 JPY cumulative volume limit, ZERO with respect to the EUR net
4 position limit, -925,000 USD toward the USD net position
5 limit, and +110,250,000 JPY toward the JPY net position limit.
6 Further supposing that the instrument valuations in agent B's
7 home currency of USD are 0.9200 EUR:USD and 0.009090 JPY:USD,
8 then the account stands $(2M \times 0.9200 + 925,000 + 110,250,000 \times$
9 $0.009090 =)$ 3,767,172.50 USD toward the notional USD
10 cumulative volume limit (useful for limiting settlement risk),
11 and $(0 \times 0.9200 + 925,000 + 110,250,000 \times 0.009090 =)$
12 1,927,172.34 USD toward the absolute notional net position
13 total.
14

15 Now suppose agent B buys 1 lot of USD:JPY at 121.50,
16 which upon settlement will result in 1,000,000 USD received
17 and 121,500,000 JPY paid. The net single-instrument positions
18 are now 0 EUR, 75,000 USD, and -10,250,000 JPY. Rather than
19 delivering JPY at settlement (which will entail carrying a JPY
20 debit balance in the account), agent B will probably choose to
21 arrange an odd-lot deal with agent A to buy 10,250,000 JPY at
22 a rate of, for instance, 121.40 USD:JPY, at a cost of
23 84,431.63 USD, resulting in final account position values of 0
24 EUR, -9,431.63 USD, and 0 JPY. In other words, agent B has
25 lost 9,431.63 USD in its account with agent A once all the
26 settlements occur.
27
28

1 Alternatively, agent B may choose to "roll forward" any
2 EUR or JPY net position from the spot date to the next value
3 date, or to any forward date by buying or selling an
4 appropriate FX swap instrument from or to agent A.
5

6 Odd-lot spot, odd-lot forward, odd-lot swap, and deals
7 with a specific counterparty 2 are not amenable to trading via
8 the "limit-order book" matching system, but instead may be
9 facilitated by the central computer 1 through a request-for-
10 quote mechanism. Since the central computer 1 knows the net
11 positions of all the accounts, it may further recommend such
12 deals on a periodic basis, such as a particular time that both
13 agents 2 consider to be the end of the business day for the
14 account in question.

15 For the application of the present invention to markets
16 other than spot FX, triangular interactions between traded
17 instrument pairs are not as much a concern. The limits set by
18 credit-extending agents 5 are handled the same way, where the
19 limits on commodity holdings or currency payments are
20 translated by the central computer 1 into excursion limits
21 (how many lots an agent 2 may buy or sell) in real-time.
22

23 The present invention can be implemented in a combination
24 of hardware, firmware, and/or software. The software can be
25 written in any computer language, such as C, C++, Java, etc.,
26 or in a combination of computer languages. The hardware,
27 firmware, and software provide three levels of content: a)
28 trade screens, b) post-trade content for back offices and

1 clearing units, and c) real-time credit management content.
2 Through an API (application programming interface) 38, agents
3 2 can securely monitor and change in real time the credit
4 limits they have specified for each trading channel 3 in which
5 they participate. (Note that the maximum flow across a
6 trading channel 3 is the minimum of the trading limits
7 specified by the two agents 2 associated with the channel 3,
8 so a non-credit-extending agent 4 can only further reduce the
9 credit limits assigned by the credit-extending agent 5.)

11 The link between the agents 2 and the central computer 1
12 can be any telecommunications link--wired, wireless, Internet,
13 private, etc. Computer 1 can be located anywhere in the
14 world. It can be mirrored for purposes of data backup, to
15 increase throughput, or for other reasons; in that case, there
16 is a second central computer 1(2). The backup central
17 computer 1(2) is a network of at least one physical computer
18 operating in a closely coordinated fashion. Such a backup
19 computer 1(2) is shown in Fig. 8, and insures that there will
20 be no interruption of service with hardware, software, or
21 network 6,7 failures (neither during the failure nor during
22 the needed repairs); and further insures that the present
23 invention has the ability to recover from a disaster event.

25 Since the present invention operates on a global scale,
26 said operation has to satisfy local laws and regulations to
27 enable the services of the present invention to be provided.
28

1 The present invention is therefore designed to enable such
2 accommodations to be made.

3 The present invention supports purpose-specific "atomic
4 units" enabling trading between specific types of agents 2.
5 The basic atomic units are "type 0", "type 1", and "type 2",
6 where a "type 0 unit" involves a single pair of agents 2 where
7 one extends credit to the other, a "type 1 unit" involves a
8 single client 4 trading with a collection of credit-extending
9 agents 5, and a "type 2 unit" involves a single credit-
10 bridging agent 5 enabling a collection of its clients 4 to
11 trade with itself 5 and with each other 4.
12

13 Figure 1 illustrates the simplest atomic unit, type 0. A
14 first agent 2(1) and a second agent 2(2) wish to trade at any
15 given time some number of round lots of instrument L in
16 exchange for a quantity of another item Q, which we refer to
17 as the quoted instrument or quoted currency. A trading
18 channel 3 (account) between the two agents 2 allows for the
19 execution of the trades and settlement of the underlying
20 instruments. Inherent in the trading channel 3 are flow
21 limits (trading limits) on the items L,Q being traded and
22 limits on any underlying instruments exchanged upon settlement
23 of the L,Q trade. A central computer 1, under control of the
24 operator or owner of the system, is coupled to the two agents
25 2. The computer 1 is adapted to convey to each agent 2
26 current bid orders and offer orders originating from the other
27 participating agent 2. The current set of tradable bid and
28

1 offered prices and sizes is constrained by the trading
2 channel's trading limits, and is preferably conveyed in the
3 form of a custom limit order book 24,25 for each agent 2, as
4 will be more fully described below. The custom limit order
5 book 24, 25 is a chart, typically displayed on the agent's
6 computer, of a preselected number of bids and offers for the
7 instrument pair L,Q in order of price, and within price, by
8 date and time (oldest first).
9

10 Typically, but not necessarily, each agent 2 is coupled
11 to the central computer 1 when the agents 2 are trading. The
12 identification of one of the two agents 2 as the "credit-
13 extending agent 5" is necessary only for the creation of a
14 trading channel 3, since either agent 2 may post orders
15 (making the market) in the same way.

16 Figure 2 illustrates the type 1 atomic unit: a client
17 agent 4 is looking to trade with several credit-extending
18 agents 5 with whom it 4 has a credit relationship. Note that
19 because each credit-extending agent 5 participates in only a
20 single trading channel 3 (with which the central computer 1 is
21 aware), there is no opportunity for the credit-extending
22 agents 5 to act as credit-bridigng agents 5. The type 1
23 scenario involves the client 4 placing a one-way or a two-way
24 order via computer 1. Computer 1 insures that every
25 institution 5 with which the client 4 has a credit
26 relationship sees the order instantaneously. If none of the
27 institutions 5 wish to deal at the client's current price,
28

1 they 5 may post their own counter-offers that then appear on
2 the client's custom limit order book 24,25, but not on those
3 of the other institutions 5. The client 4 may then choose to
4 modify or cancel its 4 order to deal at the best price
5 possible, while the institutions 5 benefit by seeing this
6 client's 4 possible interest in buying or selling.
7

8 The institutions 5 may also supply via computer 1
9 tradable bid and offered prices to the client 4 that will not
10 be seen by the other institutions 5.

11 The solid lines in Figure 2 represent credit
12 relationships between client 4 and credit-extending agents 5.
13 The credit-extending agents 5 may have credit relationships
14 outside the scope of the present invention, but only those
15 trading channels 3 whose credit limits are maintained by the
16 central computer 1 are illustrated or discussed. The dashed
17 lines in Figure 2 represent communication links between the
18 agents (4,5) and the central computer 1.
19

20 As a sub-species of type 1, there can be multiple clients
21 4, as long as all such clients 4 have credit relationships
22 with the same credit-extending agents 5, and the clients 4 are
23 not allowed to trade with each other 4.

24 Computer 1 provides several post-trade capabilities to
25 the client 4 and to the financial institution's 5 trading desk
26 as well as to its 5 back office and credit desk, all in real-
27 time.
28

1 The clearing of the trade is done by conventional means.
2
3 The operator of computer 1, though it could, does not need to
4 act as a clearing agent and does not need to hold as
5 collateral or in trust any financial or other instruments.
6 The client 4 can direct that all clearing is to be handled by
7 a certain credit-extending agent 5. The clearing procedures
8 are dependent upon the instruments traded and any netting
9 agreements or special commodity delivery procedures required
10 for those instruments.

11 The type 2 atomic unit is illustrated in Figure 4. Type
12 2 enables client 4 to client 4 dealing among the clients 4 of
13 a particular credit-bridging agent 5, as well as enabling
14 client 4 to credit-extending agent 5 trading. As usual, the
15 anonymous order-matching process is triggered whenever an
16 order to buy is made at a price equal to or higher than the
17 lowest outstanding offer to sell, or vice versa. If the match
18 is between a client 4 and the credit-bridging agent 5, then a
19 single deal is booked between those two parties 2. However,
20 if the match is between two clients 4, then two back-to-back
21 deals are booked, one between the seller client 4 and the
22 credit-bridging agent 5, and the other between the buyer
23 client 4 and the credit-bridging agent 5. This is akin to
24 creating virtual trading channels between the clients 4. A
25 client 4 who has a credit relationship with the credit-
26 bridging agent 5 is able to post its one-way or two-way order
27 via computer 1, which causes the order to be instantly
28

1 displayed to all other clients 4 and to the credit-bridging
2 agent 5 itself if the existing credit limits between the
3 posting client 4, the credit-bridging agent 5, and the
4 receiving client 4 would allow a portion of the order to be
5 executed.
6

7 This "mini-exchange" has the liquidity of the natural
8 supply and demand of the entire client 5 base, combined with
9 the market-making liquidity that the credit-bridging agent 5
10 would be supplying to its clients 4 ordinarily. It is
11 certainly expected, and beneficial to the overall liquidity,
12 that the credit-bridging agent 5 will be able to realize
13 arbitrage profits between the prices posted by its clients 4
14 and the prices available to the credit-bridging agent 5
15 through other sources of liquidity. In fact, there may be
16 instances in some markets where clients 4 are also able to
17 arbitrage against other trading systems.
18

19 Again, computer 1 provides several post-trade
20 capabilities to the client 4 and to the trading desk, the back
21 office, and the credit desk of the credit-bridging agent 5,
22 all in real-time, as in type 1.

23 A pair of back-to-back trades is illustrated in Figure 5,
24 showing that agents 4(2) and 4(4) are the ultimate buyer and
25 seller of the deal, but they each deal only with the credit-
26 bridging agent 5 as their immediate counterparty 2.

27 As with all the various atomic units, central computer 1
28 updates the current tradable information after each trade, and

1 causes this information to be displayed on the computers
2 associated with all of the subscriber agents 2.

3 Again, computer 1 provides several post-trade
4 capabilities to the clients 4, as well as to the credit-
5 bridging agent's 5 trading desk, its 5 back office, and its 5
6 credit desk, all in real-time. The credit-bridging agent 5
7 acts as a clearing agent for this trade, and is able to
8 monitor the client-to-client exposure, in real time.
9

10 Thus is created a price-discovery mechanism for end-users
11 2 with direct transparency between entities 2 wishing to take
12 opposite sides in the market for a particular instrument. The
13 present invention encompasses decentralized operation of an
14 arbitrary number of separate, type-1 and type-2 atomic units.
15 Efficient price discovery is provided to the end user 2 in a
16 decentralized liquidity rich auction environment, leveraging
17 existing relationships, and co-existing with and indeed
18 benefiting from traditional trading methodologies.
19

20 Furthermore, an arbitrary number of different type 0,
21 type 1, and type 2 atomic units may be interconnected, bottom-
22 up, as illustrated in Fig. 6, to provide, at all times, a
23 liquidity rich efficient price-discovery mechanism to the
24 subscribing agents 2, enabling more and more agents 2, across
25 different atomic types, to conduct efficient direct auctions
26 with each other directly. The various atomic units may be
27 interconnected into a molecular credit-network.
28

1 In Figure 6, which may be considered to illustrate a
2 "type 3" scenario, shaded circles represent credit-bridging
3 agents 5 and un-shaded circles represent clients 4.

4 For purposes of simplicity, central computer 1 is not
5 shown on Fig. 6, but is in fact coupled to all nodes 2. Each
6 node 2 has proprietary client software on a computer
7 associated with said node 2, enabling said node 2 to
8 communicate with central computer 1. Such software may take
9 the form of a Web browser. The diameters of the arrow-headed
10 lines 3 represent instrument excursion limits deduced from
11 each trading channel's various types of credit limits. A
12 "shortest weighted paths" algorithm or other minimum cost flow
13 algorithm is used to calculate the minimal path between two
14 agents 2 subject to credit flows to enable a trade between the
15 agents 2. The trading agents 2 may be arbitrarily removed
16 from one another, both in geographic terms as well as by type
17 of business activity in which they 2 are involved.

18 Each connected piece of Fig. 6 maintains full
19 transparency of orders posted on computer 1 to all financial
20 institutions 5 and clients 4 who are on any unexhausted credit
21 path 3 to the posting entity 2. Each of the entities 2 who
22 are able to see the posted order are in effect competing,
23 through the reverse auction, for that particular deal,
24 enabling further efficient price-discovery to the posting
25 entity 2.
26
27
28

1 Prior to each trade, computer 1 internally computes the
2 values that define one of these Figure 6 graphs for each pair
3 of instruments being traded. From the graph, computer 1
4 creates a table of multi-hop trading limits showing the
5 trading limits between each pair of nodes 2. From the table
6 of multi-hop trading limits, computer 1 prepares a custom
7 limit order book 24,25 for each node 2 for each traded
8 instrument pair. After every trade, computer 1 recalculates
9 the trading limits 3, thus leading to a new graph (Figure 6)
10 for that instrument pair. Recalculating the trading limits 3
11 for a given traded instrument pair can affect the topology
12 (trading limits 3) of other graphs (Figure 6) for other traded
13 instrument pairs. This can occur, for example, when the
14 trading limits are notional trading limits.

15
16 On Figure 6, if an agent 2 has imposed its own internal
17 limits that are smaller than the trading limits that have been
18 imposed by a credit-extending agent 5 that is extending it 2
19 credit, computer 1 uses the smaller of the two limits when it
20 creates Figure 6.

21
22 Each trading channel 3 represents an account between a
23 credit-extending agent and a client agent 4. In the preferred
24 implementation of this invention, all credit-extending agents
25 are credit-bridging agents 5. Even when two adjacent nodes 2
26 are fully qualified to be credit-extending agents 5, one acts
27 as the credit-extending agent 5 in the transaction and the
28 other acts as the client agent 4 in the transaction. The

1 accounts that exist between credit-extending agents 5 and
2 client agents 4 comprise specified input credit limits,
3 balance holdings, and collateral; computer 1 calculates
4 trading limits from this information.
5

6 The operator of computer 1 typically has, in its standard
7 agreement with a subscribing agent 2, language stating that if
8 the agent 2 has entered into a written subscription agreement
9 with the operator of computer 1 and said agent 2 trades
10 outside of the network 6,7 operated by the operator of
11 computer 1, that agent 2 is obligated to notify the operator
12 of computer 1 about such outside trades, so that computer 1
13 can recalculate the trading limits as necessary.
14

15 Figure 6 can be thought of as an n-hop credit network,
16 where n is an arbitrary positive integer. In any transaction,
17 the instrument flow can fan out from one source node 2 and
18 then collapse to the destination node 2; the instrument flow
19 does not have to stay together as it flows from the source 2
20 to the destination 2. See Fig. 11 for an example of this
21 phenomenon. In calculating the maximum capacity of the
22 network 6,7, computer 1 uses a maximum flow algorithm such as
23 one described in chapter 7 of the Ahuja reference cited
24 previously. In determining the actual flow used to complete
25 the trade, computer 1 uses a minimum cost flow algorithm such
26 as one described in chapter 9 of said Ahuja reference, where
27 the cost to be minimized is a function of the actual cost to
28 execute the trade and other factors, such as projected

1 settlement costs, flow balancing heuristics, and a randomizing
2 component.

3 The network 6,7 of Figure 6 is a non-disjointed network.
4 By that is meant that every node 2 in the network 6,7 is
5 coupled to at least one other node 2, and at least one of the
6 agents 2 associated with each trading channel 3 is a credit-
7 bridging agent 5. The individual trading limits 3 that
8 computer 1 computes for each agent 2 pair are dependent upon
9 the topology of the network 6,7. Computer 1 essentially
10 transforms the network 6,7 into a virtually cliqued networked.
11 A "cliqued network" is one in which every node 2 is connected
12 to every other node 2. A "virtually cliqued network" is one
13 in which every node 2 has a capability to trade with every
14 other node 2, but not necessarily directly. In order to
15 preserve the desired feature of anonymity, each node 2 knows
16 the identities of only its immediate trading partners 2, and
17 does not necessarily know whom 2 it is actually trading with.
18

19 As a trading system that leverages the existing
20 relationships in the market for the traded instrument, the
21 present invention provides all market players 2 (typically
22 banks, financial institutions, clearing entities, hedge funds,
23 and any corporations or other entities) the ability to trade
24 directly with each other through a custom limit order book
25 24,25. These agents 2 may already be connected together with
26 credit relationships, but prior art systems allow trading only
27 between two parties that have an explicit credit arrangement.
28

1 The present invention analyzes the credit-worthiness of a
2 potential counterparty 2 at a higher level, performing this
3 analysis in real time, and providing each party 2 with a limit
4 order book 24,25 customized to its 2 current credit
5 availability.
6

7 For example, in Figure 7 we consider a small network of
8 foreign exchange players: banks 5(B) and 5(C), which have a
9 credit relationship with each other, and clients 4(A) and
10 4(D), who have margin placed with banks 5(B) and 5(C),
11 respectively (we leave the margin currency and traded
12 instrument unspecified). The specified input credit limits
13 are specified as traded instrument L:Q credit limits (just one
14 way of specifying input credit limits out of eight possible
15 ways enumerated in the present patent application). Client
16 4(A)'s margin allows it to trade +/- 10M with 5(B), 5(B)'s
17 relationship allows it to trade +/- 50M with 5(C), and 5(D)'s
18 margin allows it to trade +/- 5M with 5(C). This information
19 is supplied to computer 1, which draws Figure 7 from said
20 information.
21

22 Figure 7 illustrates a simplified type 3 network in which
23 there are two client agents 4 and two credit-extending agents
24 5 which are also credit-bridging agents 5. Figure 7 also
25 illustrates the trading limits between each pair of coupled
26 agents 4,5. Table 1 shows the maximum multi-hop credit limits
27 that are then calculated by computer 1 for the simplified
28 network of Figure 7 as follows:

Table 1:

	A	B	C	D
A	infinity	10M	10M	5M
B	10M	infinity	50M	5M
C	10M	50M	infinity	5M
D	5M	5M	5M	infinity

Computer 1 then uses the information contained in Table 1 to create a custom limit order book 24,25 for each agent A, B, C, D, and causes the custom limit order book 24,25 to be displayed on the computer screen of the respective agent A, B, C, D. The filtered bids and offers in the custom limit order book 24,25 are for volumes that are an integral multiple of the lot size even if the computed Table 1 amounts contain values which are not integral multiples of the lot size, with non-integral multiples rounded toward 0.

If client A posts a bid for 10M, computer 1 causes the full bid to appear on the custom limit order books 24,25 of banks B and C, and computer 1 causes a filtered bid for 5M to appear on the custom limit order book 24,25 of client D, because the maximum credit (implicit or explicit) available between A and D is +/- \$5M. If there is no implicit or explicit credit available between two nodes 2, they 2 are not

1 allowed to see each other's bids and offers at all on their
2 custom limit order books 24,25.

3 The network 6,7 of the present invention is preferably
4 built using the Internet Protocol (IP) (because of its
5 ubiquity), and may reside on the Internet itself or other
6 public IP network 7 (Fig. 8).
7

8 It is also possible to locate part or all of the network
9 6,7 on a private fiber backbone 6, so that information bound
10 for the Internet 7 can traverse most of the distance to its
11 destination on the presumably higher speed private network 6.
12 The slower public Internet 7 is then used for just the last
13 segment of travel. It is also possible to provide clients 2
14 with dedicated bandwidth through private IP networks 6 in
15 order to provide additional levels of quality and service. A
16 single dedicated connection 6 may be backed up by an Internet
17 connection 7, or multiple private connections 6 can be used to
18 avoid the public network 7 entirely.
19

20 On Figure 8, the three illustrated agents 2 can be three
21 separate companies, three computers within the same company,
22 or a hybrid of the above.

23 The network 6,7 interfaces with both people and automated
24 systems (computers), so it provides three access methods:

25 □human -- Graphical User Interface (standalone or browser-
26 based application) for trading, interactive queries, and
27 account management;
28

1 □human/computer -- HTTP reports interface (HTML, XML, PDF,
2 or Excel) for queries only;

3 □computer -- Application Programming Interface 38
4 (available in Java and COBRA with bridges to FIX, JMS,
5 SOAP, and ebXML) for trading, queries, and account
6 management.
7

8 An agent's 2 software can be launched from the agent's 2
9 browser but run as a standalone application for better
10 performance and stability.

11 The computer of each agent 2 can have associated
12 therewith an application programming interface (API) 38. The
13 API 38 is a standard interface exposed by the central computer
14 1 that enables the user 2 to write customized instructions
15 enabling two-way communication between central computer 1 and
16 the user 2. In the case where the user 2 is a credit
17 extending agent 5, the API 38 can be used to update the
18 agent's backoffice information. The agent 2 can program his
19 API 38 to make and cancel orders (bids and/or offers). The
20 agent 2 can use his API 38 to receive and reformat custom
21 limit order books 24,25 for any instruments. The agent 2 can
22 use his API 38 to set trading limits, with the understanding
23 that the actual trading limits are the minimum of the trading
24 limits specified by the two agents 4,5 associated with an
25 account. The API 38 can be programmed to estimate how much it
26 would cost an agent 2 to liquidate his position in an
27 instrument. The API 38 can be programmed to estimate that
28

1 agent's profit/loss amount for each instrument being traded;
2 this information can be combined with the agent's custom limit
3 order book 24, 25. Anything that can be achieved by the GUI
4 (graphical user interface) (Figs. 13-22) can be achieved via
5 the API 38.
6

7 Any and all features of the API 38 can be programmed to
8 operate automatically, including automatic bidding, offering,
9 buying, and selling. Automated processes accessing computer 1
10 via application programming interface 38 or a bridge use the
11 same cryptographic protocols as for a human agent 2 inputting
12 instructions via his computer's GUI. Whether an API 38 or a
13 GUI is used, an agent's private key for computerized access to
14 computer 1 can be stored in the agent's computer, provided
15 said computer has sufficient security safeguards.
16

17 Privacy, authentication, and non-repudiation are achieved
18 in the present invention via the use of cryptography in a
19 variety of different forms. The cryptographic techniques can
20 comprise symmetric key and/or asymmetric key (public key)
21 cryptography. All data streams are encrypted, e.g., by using
22 SSL (Secure Socket Layer) connections or a combination of SSL
23 encryption with additional authentication and encryption.
24 Authentication can be required between computer 1 and an agent
25 2 at any and all times these devices 1,2 communicate with each
26 other. This authentication can be achieved through the use of
27 digital certificates. Revalidation of credentials can be
28 required at the time a trade is consummated.

1 Each agent 2 may store its private key on a tamper-
2 resistant hardware device such as a smartcard, protected by a
3 password. The combination of a physical token (the card) with
4 a logical token (the password) ensures two levels of security.
5 The hardware token may contain a small CPU that allows it to
6 perform the necessary cryptographic operations internally, so
7 that the agent's private key never leaves the smartcard. In a
8 preferred embodiment, computer 1 handles bulk
9 encryption/decryption using symmetric key cryptography after
10 the slower public key cryptography has been used to exchange a
11 session key between agent 2 and computer 1.

12 While trading in the present invention is peer-to-peer,
13 order matching for any particular instrument is done at a
14 centralized location 1 to maintain transactional integrity.
15 Figure 9 illustrates the order matching process. In step 8,
16 the first agent 2(1) places a bid via its software to computer
17 1, which accepts the bid at step 9. Computer 1 then
18 calculates changes to the custom limit order books 24,25 of
19 agents 2(1) and 2(2) at steps 10 and 11, respectively, taking
20 into account appropriate trading limits 3. At step 12, the
21 second agent 2(2) takes the bid. Step 12 occurs right before
22 step 13, in which a third agent 2(3) (not illustrated) posts a
23 new offer (bid or offer) for the traded instrument L:Q. At
24 step 14, computer 1 makes the match between the first agent
25 2(1) and the second agent 2(2).
26
27
28

1 Reporting of the trade is described below in conjunction
2 with Figs. 35 and 36.

3 A network 6,7 implementing the present invention can span
4 the entire world, which means that there may be time
5 differences for a message sent by different agents 2 to
6 computer 1. Assuming a network 6,7 that sends signals at the
7 speed of light but that cannot transmit through the Earth, a
8 message sent to the other side of the Earth would have a
9 round-trip time of at least 130 milliseconds. On existing IP
10 networks, it is observed that if the central computer 1 were
11 located in New York, the maximum average round-trip
12 communication time between the central computer 1 and a
13 computer in any of the major financial centers is less than
14 300 milliseconds.

15 We want to ensure that all agents 2 have a level playing
16 field in accessing computer 1, regardless of where these
17 agents 2 are situated around the world. Determining the
18 latency for each agent 2 and then introducing an individual
19 delay on an agent-by-agent basis to try to equalize time-of-
20 arrival at computer 1 would be very difficult (due to short
21 term fluctuations in network 6,7 lag), and could have the
22 undesired effect of overcompensating. A malicious agent 2
23 could also falsify its network 6,7 delay, unfairly obtaining
24 early access to computer 1.

25 In order to compensate for the various time lags in
26 sending messages between agents 2 and computer 1 on a global
27
28

1 basis, the present invention transmits information as rapidly
2 as possible while flagging the order of messages to compensate
3 for latency. The flagging is done by means of border outpost
4 computers 16 (Figure 10).

5 For agents 2 remote from computer 1, a border outpost
6 computer 16 is inserted into the network 6,7, typically where
7 the agent's data enters the private backbone 6 that connects
8 to computer 1. Each border outpost computer 16 comprises a
9 CPU 18, a trusted time source 17, and an input/output port 19.
10 Time source 17, which may comprise a GPS clock accurate to a
11 millionth of a second, is used to generate a digital time
12 stamp that is added to each data packet before it is forwarded
13 to computer 1. The GPS clocks 17 of all the border outpost
14 computers 16 are synchronized with each other to a high degree
15 of accuracy (typically one microsecond). The time stamp may
16 be placed onto the packet without the border outpost computer
17 16 having to understand the packet or have access to its
18 contents. At the computer 1 site, the time stamp is stripped
19 off before the packet is processed, and then reassociated with
20 the data after it is decrypted and parsed into a command.
21 Computer 1 then sorts the messages into a queue by time order.
22 After a fixed time delay, the message that is at the front of
23 the queue is serviced by computer 1. The fixed time delay is
24 chosen so that with a high degree of certainty a message from
25 the remotest agent's 2 computer will arrive at computer 1
26 within the fixed time delay. The purpose of the fixed time
27
28

1 delay is to allow all messages that might be the first-
2 originated message to have a chance to arrive at computer 1
3 before execution of any messages takes place. The time stamp
4 may be encrypted using either a symmetric or assymetric
5 cipher, to prevent its modification or falsification.
6

7 Figure 11 is a deal fulfillment (flow) graph,
8 illustrating the flow in the lot instrument. The lot
9 instrument L is the portion of the traded instrument that has
10 to be traded in a round lot, typically a multiple of a
11 million. The quoted instrument Q is that portion of the
12 instrument being traded that is expressed as the lot
13 instrument times a price. In this example, agent 4(2) buys
14 10M Euros using U.S. dollars at an exchange rate of 0.9250
15 from agent 4(1). Since the Euro is the lot currency in this
16 example, it has to be specified in a round lot (multiple of 1
17 million Euros). $F(L)$, the lot size (volume), is 10 million
18 and $F(Q)$, the quoted volume, is 9,250,000. In this example,
19 there are three intermediaries (middlemen): agents 5(1), 5(2),
20 and 5(3). Only credit-bridging agents 5 can be middlemen.
21 For purposes of simplification, we show on Figure 11 the flow
22 of just the lot instrument L. There is also a counterflow in
23 the quoted instrument Q, which can be derived from the lot
24 flow and the traded price. For example, on the edge 3 between
25 node 5(1) and 4(2,) 2M represents the flow of 2 million Euros
26 from agent 5(1) to agent 4(2), as well as the counterflow of
27 1,850,000 U.S. dollars from agent 4(2) to agent 5(1).
28

1 Figure 12, a simplified focus change diagram, illustrates
2 the sequence of screen shots appearing on the display of a
3 computer of an agent 2 who is coupled to central computer 1.
4 Agent 2 first encounters a log-in dialog box 21, then a menu
5 bar 22 where he can select from an account management dialog
6 box 23, a net exposure screen 35, a balance sheet 36, or his
7 custom limit order book 24,25. From custom limit order book
8 overview screen 24, agent 2 can navigate to one of N order
9 book detail screens 25, or to an activity dialog screen 27,
10 which can take the form of a bid dialog box 28, an offer
11 dialog box 29, a buy dialog box 30, a sell dialog box 31, or a
12 market order screen 32. As shown in Figure 12, various of
13 these screens can segue into a bid/offer cancel dialog box 33
14 or a confirmation dialog box 34.

15
16 Figures 13-22 illustrate most of the above screens. The
17 login screen is shown (Figure 13), followed by two shots of
18 the main desktop (Figures 14 and 15) showing the custom limit
19 order book overview window 24 and the custom limit order book
20 detail window 25. The remaining screen shots (Figs. 16-22)
21 are of dialog boxes that can be activated from either the
22 overview window 24 or detail order windows 25.

23
24 Figure 13 illustrates log-in dialog box 21. Field 41
25 allows agent 2 to type in his name, thus identifying the
26 account and trader. Field 42 is an optional challenge field,
27 provided for security purposes. An appropriate response from
28 the agent 2 to meet the challenge might include presentation

1 of a password, key, or digital certificate via a hardware
2 token. Field 43 is where agent 2 enters his password. Field
3 44 is where agent 2 enters the address of central computer 1.
4 In the case of an Internet connection, the URL of computer 1
5 is specified here. The data exchange between agent 2 and
6 central computer 1 is encrypted, e.g., by a SSL (Secure Socket
7 Layer) connection. Field 45 is a scrolling message log
8 showing status and notification of errors during the log-in
9 process.
10

11 Figure 14 illustrates the main custom limit order book
12 screen. Field 51 specifies the current account. Field 52 is
13 a summary of the custom limit order book for each permissioned
14 traded instrument. In this sample, where the instruments are
15 pairs of currencies, the traded instruments are identified by
16 icons representing the flags of the countries issuing the
17 currencies. There are five fields 52 illustrated,
18 representing five permissioned instruments. The second field
19 52 from the top (Great Britain pounds for U.S. dollars) is
20 exploded, indicating the traded instrument currently activated
21 by agent 2.
22

23 Field 53 displays the top (best) orders from the point of
24 view of the agent 2. Field 54 displays the best bid price for
25 any agent 2 coupled to the network 6,7. Field 55 displays the
26 last two digits ("84") of the best available bid price. Field
27 56 displays the size at the best bid price. Field 57 displays
28 agent 2's available liquidity for additional selling. Field

1 58 provides agent 2 with a mouse-clickable area (the big
2 figure) enabling the agent 2 to jump to the buy or sell dialog
3 screen 30 or 31, with amounts already filled in. Field 59 is
4 a mouse-clickable numeric keypad allowing the agent 2 to
5 create and cancel orders. Field 60 gives balance sheet values
6 showing live valuations at market price and the profit that
7 was banked by agent 2 for a certain period of time, such as
8 the current day. Field 61 is a pop-up console allowing for
9 the display of application messages, connection failure/retry
10 messages, and broadcast messages from central computer 1.
11 Field 62 displays the time since the agent 2 has logged in to
12 computer 1. Field 63 displays the best available offer; in
13 this case, four digits of the available offer are used to warn
14 agent 2 that his best available offer is far from the overall
15 best, due to a credit bottleneck. Field 64 shows this agent's
16 orders in red. Field 65 shows this agent's current net
17 position in the instrument being traded. Field 66 shows a
18 summary of this agent's offers. Field 67 is a mouse-clickable
19 area (tab 9) enabling the agent 2 to quickly cancel the top
20 offer.
21
22

23 Figure 15 illustrates a custom limit order book depth
24 window 25. There are N of these windows 25 for each
25 instrument, where N is any preselected positive integer.
26 Typically, N is equal to five. The N windows 25 display the N
27 best bids and offers in order of price, and within price, in
28 order of date and time, with the oldest presented first.

1 Field 71 shows bid and offer information, with the last two
2 digits of the bid and offer ("99" and "02", respectively)
3 displayed in large numerals for readability. Field 72 shows
4 visible (to that agent 2) bids and offers truncated by current
5 credit availability, individually or aggregated by price
6 (configurable). Bids and offers from this agent's account are
7 shown in pink. Field 73 is a mouse-clickable field allowing
8 agent 2 to navigate to screen 33 (Fig. 18). Field 74 is a set
9 of four mouse-clickable areas enabling agent 2 to open buy,
10 sell, bid, and offer dialog boxes (30, 31, 28, and 29,
11 respectively), with price and size information pre-loaded from
12 the current market.
13

14 Figure 16 illustrates net exposure monitor 35. Each
15 entry 81 gives the current exposure for each account, broken
16 down by traded instrument. Field 82 ("min" and "max") shows
17 asymmetric net position limits on a per-instrument basis.
18 Field 83 ("current") shows a real-time update of net position.
19 Field 84 shows a graphical representation of net position.
20

21 Figure 17 illustrates balance sheet window 36. Field 91
22 shows payables and receivables, valued using the current
23 market price. Total net position and net position for each
24 counterparty 2 are given. Field 91 is organized as a tree
25 hierarchy, and allows navigation to individual balance sheet
26 transfers. Field 94 shows underlying flows; they have been
27 sent to the agent's computer in an encrypted form, and are
28 decrypted at the agent's computer. The decryption can be done

1 automatically, as long as the agent 2 is logged in to the
2 network 6,7. In field 94, one line represents each trade this
3 agent 2 has made, or each trade for which this agent 2 was an
4 intermediary 5. All values are live. This currency-based
5 balance sheet 36 is capable of handling triangular instrument
6 swaps.
7

8 Figure 18 illustrates the open order overview and
9 management window 33. Field 101 shows orders (bids and
10 offers) currently placed by that agent summarized by traded
11 instrument. Field 102 shows individual orders. Field 103 is
12 a mouse-clickable area enabling the agent 2 to remove the
13 order from the agent's custom limit order book 24,25. All
14 values are updated immediately if their value has changed. In
15 screen 33, an update procedure can be implemented in which the
16 first offer is not cancelled until a new offer is posted.
17 This is sometimes referred to as OCO (one cancels the other).
18 In any event, it is never possible for an agent 2 to cancel an
19 order after it has been taken by a counterparty 2.
20

21 Figure 19 illustrates bid creation dialog box 28. Field
22 111 is a group of icons, typically in various colors to
23 provide visual context to reduce errors. Note that the word
24 "Bid" is highlighted. Field 112 comprises three mouse-
25 clickable areas allowing for quick up or down adjustment of
26 price and direct entry of price, respectively, with initial
27 value taken from the current market. Field 113 comprises
28 three mouse-clickable areas allowing for quick up or down

1 adjustment of size, and direct entry of size, with initial
2 value configurable based upon the desires of the particular
3 agent 2. Field 114 is a mouse-clickable area allowing the
4 agent 2 to submit the bid, and has an optional confirmation
5 dialog box associated therewith. An agent 2 can post his bid
6 for just a short period of time and then withdraw it. He 2
7 can post multiple bids at multiple prices. When a
8 counterparty 2 takes part or all of his bid, computer 1
9 recalculates the trading limits. Agent 2 can make his bid
10 limited to "only if it is available now" or as an offer to
11 buy.
12

13 Figure 20 illustrates offer creation dialog box 29.
14 Field 121 comprises a set of icons, typically colored to
15 provide visual context to reduce errors. Note that the word
16 "Offer" is highlighted. Field 122 comprises three mouse-
17 clickable areas allowing agent 2 to quickly achieve up or down
18 adjustment of price and direct entry of price, with initial
19 value taken from the current market. Field 123 comprises
20 three mouse-clickable areas providing a quick means for agent
21 2 to achieve up or down adjustment of size and direct entry of
22 size, with initial value configurable on a per user 2 basis.
23 Field 124 is a mouse-clickable area allowing agent 2 to post
24 the offer, and has an optional confirmation dialog box
25 associated therewith.
26

27 Figure 21 illustrates buy (immediate execution bid)
28 dialog box 30. Field 131 comprises a set of icons, typically

1 colored to provide visual context to reduce errors. Note that
2 the word "Buy" is highlighted. Field 132 comprises three
3 mouse-clickable areas, providing a quick means for up or down
4 adjustment of price and direct entry of price, with initial
5 value taken from the current market. Field 133 is a mouse-
6 clickable button allowing for a partial execution of a trade.
7 This allows agent 2 to buy either as much of the size as
8 possible, or nothing if he cannot buy the entire size. Field
9 134 comprises three mouse-clickable areas providing a quick
10 means for up or down adjustment of size and direct entry of
11 size, with initial value configurable on a per user 2 basis.
12 Field 135 is a mouse-clickable area allowing agent 2 to
13 execute the buy, and has an optional confirmation dialog box
14 associated therewith.
15

16 Figure 22 illustrates sell (immediate execution offer)
17 dialog box 31. Field 141 is a set of icons, typically colored
18 to provide visual context to reduce errors. Note that the
19 word "Sell" is highlighted. Field 142 comprises three mouse-
20 clickable areas providing a quick means for agent 2 to achieve
21 up or down adjustment of price and direct entry of price, with
22 initial value taken from the current market. Field 143 is a
23 mouse-clickable area allowing partial execution. This allows
24 agent 2 the choice of the sell being either to fill as much of
25 the size as possible, or to not sell if he 2 cannot sell the
26 entire size. Field 144 comprises three mouse-clickable areas
27 providing for a quick means for up or down adjustment of size
28

1 and direct entry of size, with initial value configurable on a
2 per user 2 basis. Field 145 is a mouse-clickable area
3 allowing the sell to be executed, and has an optional
4 confirmation dialog box associated therewith.
5

6 Figure 23 is a flow diagram illustrating the method steps
7 by which computer 1 computes a custom limit order book 24,25
8 for a single agent 2 for a single traded instrument. Even
9 intermediate agents 5 get a custom limit order book 24, 25.
10 For the left hand side of Fig. 23, source S is that node 2 for
11 which this custom limit order book is being prepared; and sink
12 T is that node 2 that has posted the bid. For the right hand
13 side of Figure 23, source S is that node 2 that posted the
14 offer; and sink T is that node 2 for which this custom limit
15 order book is being prepared. "Source" and "sink" are
16 standard network terminologies; see, e.g., the Ahuja reference
17 previously cited. These concepts are used internally by
18 computer 1, but are not disclosed to all agents 2 for reasons
19 of preserving the desired anonymity. For example, the actual
20 poster 2 of the offer does not appear on the screen of the
21 counterparty 2.
22

23 The method starts at step 151. In step 152, computer 1
24 asks whether there have been any trades made since the last
25 multi-hop credit computation. This is meant to avoid
26 unnecessary computation. If the answer to the question is
27 "yes", then step 153 is executed. At step 153, multi-hop
28 credit limits are computed, as illustrated in Fig. 24. If the

1 answer to the question raised in step 152 is "no", step 154 is
2 executed. At step 154, the bid side of the book is cleared,
3 i.e., variable B becomes the null set; the offer side of the
4 book is cleared, i.e., variable A becomes the null set; and
5 the credit used (U as a function of S and T) is cleared. In
6 this context, "used" applies only for this particular custom
7 limit order book 24,25 for this particular agent 2. Step 155
8 is then executed, where it is asked whether enough bids have
9 been found. "Enough" is a pre-established limit, e.g., five,
10 and corresponds to N as discussed above in conjunction with
11 custom limit order book detail window 25. N may be infinity,
12 in which case the method always proceeds from step 155 to step
13 156. If enough bids have been found, the method proceeds to
14 step 161. If enough bids have not been found, the method
15 proceeds to step 156, where it is asked whether there are more
16 unprocessed bids, i.e., if the number of bids that have been
17 processed is less than the pre-established limit. If the
18 answer is "no", step 161 is executed; otherwise, the method
19 proceeds to step 157, where the highest priced oldest
20 unprocessed bid is fetched. The hierarchy is according to
21 highest bid. If there is a tie as to two or more highest
22 bids, then the bids are ordered by time. It is forced that
23 there not be a time-tie at this point; time collisions have
24 already been resolved by locking using sequence numbers.

25
26
27 Step 158 is then executed. X is defined as the flow
28 limit (trading limit) between S and T minus the credit U

1 between S and T that has already been used up. Y is then set
2 to be the minimum of X and the bid size. In other words, Y is
3 what we have to work with. Step 159 is executed, where it is
4 asked whether Y is greater than 0. If not, the method cycles
5 back to step 155. If "yes", step 160 is executed. In step
6 160, the set of bids B is augmented by the current bid we are
7 working with from step 157. Also in step 160, the credit used
8 U is augmented by Y.
9

10 At step 161, it is asked whether enough offers have been
11 found. Again, "enough" is a pre-established limit e.g., five,
12 corresponding to N as before. If the answer to this is "yes",
13 the method stops at step 167. If the answer is "no", step 162
14 is executed. At step 162, it is asked whether there are more
15 unprocessed offers. If not, the method ends at step 167. If
16 "yes", step 163 is executed, where the lowest priced, oldest
17 unprocessed offer is fetched. Then, step 164 is executed,
18 where X is set to be the trading limit between S and T minus
19 the unused credit U. Y is then set to be the minimum of X and
20 the offer size. Step 165 is then executed. At step 165, it
21 is asked whether Y is greater than 0. If not, control is
22 passed back to step 161. If "yes", step 166 is executed,
23 where the current offer price being worked on from box 163 is
24 added to the set of offers A; and the credit used U is
25 augmented by Y. Control then passes back to step 161.
26

27 Figure 24 illustrates how computer 1 calculates multi-hop
28 trading limits for each pair of agents 2 for a single traded

instrument L:Q, i.e., how computer 1 performs step 153 on
Figure 23. This is akin to compiling a table like Table 1
shown above. This procedure starts at step 171. At step 172,
a directed graph is computed for the traded instrument L:Q, in
which the arrow corresponds to the direction of flow of the
lot instrument L. Individual trading limits are introduced at
this point. Step 172 is the subject of Figure 25. At step
173, an arbitrary network node 2 is selected to be the first
node worked upon by the process and is given the designation
source S. At step 174, sink T is also set to be said first
network node 2. At step 175, it is asked whether S is equal
to T. If so (which, of course, is the case initially), the
procedure moves to step 176, where the maximum flow limit
between S and T is set to be infinity. This is simply another
way of saying that an agent 2 is allowed to have an infinite
flow with himself 2. Then, at step 182, it is asked whether T
is the last network node that needs to be processed. If
"yes", control is passed to step 184; if "no", control is
passed to step 183, where T is advanced to the next network
node; and control is passed back to step 175. "Next" can be
anything, because the order of processing is of no import.

If S is found not to be equal to T at step 175, control
is passed to step 177, which disables edges 3 where the edge
origin 2 is not a credit bridge 5 and the edge origin 2 is not
equal to S. An edge 3 may be disabled internally by adjusting
its maximum capacity to 0 or by removing it from the set of

edges 3 that comprise the graph. The "edge origin" is that node 2 from which the lot instrument L flows. Steps 177 and 178 eliminate agents 2 who have not agreed in advance to be intermediaries, i.e., "credit bridges". An intermediary (credit bridge) is an agent 5 that allows two other agents 2 to do back-to-back trades through the intermediary agent 5. Step 178 disables edges 3 where the edge destination 2 is not a credit bridge 5 and the edge destination 2 is not equal to T. An "edge destination" is a node 2 that receives the flow of the lot instrument L.

At step 179, the maximal flow from S to T is computed using a maximal flow algorithm such as one of the algorithms disclosed in Chapter 7 of the Ahuja reference previously cited. At step 180, the multi-hop credit limit between S and T, $LIM(S,T)$, is set to be equal to the maximum flow obtained from step 179. At step 181, the edges 3 that were disabled in steps 177 and 178 are re-enabled. Step 184 asks whether S is the last network node to be processed. If "yes", the procedure concludes at step 186. If "no", the process moves to step 185, where S is advanced to the next network node. Again, "next" is arbitrary and simply refers to any other unprocessed node 2. After step 185, the method re-executes steps 174.

Figure 25 illustrates how computer 1 calculates a directed graph for the traded instrument L:Q, i.e., how computer 1 performs step 172 of Figure 24. This is akin to

1 producing a graph such as that shown in Fig. 6, with arrows as
2 in Fig. 11. The operation commences at step 191. At step
3 192, the edge 3 set G is nulled out. At step 193, computer 1
4 searches its records for any account A that it has not yet
5 processed. The order of selection of unprocessed accounts is
6 irrelevant. Account A is any pre-existing trading (credit)
7 relationship between two neighboring agents 2 that has been
8 previously conveyed to the operator of computer 1 in writing
9 in conjunction with these agents 2 subscribing to the trading
10 system operated by the operator of computer 1.

12 Step 194 asks whether there is any such unprocessed
13 account A. If "not", this process stops at step 198. If
14 there is an unprocessed account A, the process executes step
15 195, where the minimum and maximum excursions for account A
16 are calculated. Step 195 is the subject of Figure 26. These
17 minimum and maximum excursions are defined in terms of the lot
18 instrument L, and are calculated from one or more of eight
19 possible ways of specifying input credit limits. The maximum
20 and minimum excursions are excursions from current position.
21 The input credit limits are specified as part of each account
22 A. In step 196, the set of edges G is augmented with an edge
23 3 from A's lender 2 to A's borrower 2, with the capacity of the
24 edge 3 being set to the maximum excursion. L is the lot
25 instrument and Q is the quoted instrument. In step 197, the
26 set of edges G is augmented with an edge 3 from A's borrower 2
27 to A's lender 2, with the capacity of the edge 3 being set to
28

1 the negative of the minimum excursion. The process then re-
2 executes step 193.

3 Figure 26 shows how computer 1 calculates the minimum and
4 maximum excursions for a single account A and a single traded
5 instrument L:Q, i.e., how computer 1 executes step 195 of
6 Figure 26. This computation takes into account up to eight
7 different ways a guaranteeing agent 5 may specify input credit
8 limits in an account A. The operation commences at step 201.
9 At step 202, the maximum excursion is set to be infinity and
10 the minimum excursion is set to be minus infinity, because at
11 this point there are no trading limits.

12
13 Step 203 asks whether position limits have been defined
14 for the lot instrument. If yes, step 204 is executed. At
15 step 204, the lot instrument position limits' effects on the
16 maximum and minimum excursions are calculated. This is the
17 subject of Figure 27. At step 205, it is asked whether volume
18 limits have been specified for the lot instrument. If so,
19 step 206 is executed. At step 206, the lot limit volume
20 limits' effects on the maximum and minimum excursions are
21 calculated. This is the subject of Figure 29. At step 207,
22 it is asked whether position limits have been specified for
23 the quoted instrument. If so, step 208 is executed. At step
24 208, the quoted instrument position limits' effects on the
25 maximum and minimum excursions are calculated. This is the
26 subject of Figure 28. At step 209, it is asked whether volume
27 limits have been specified for the quoted instrument. If so,
28

step 210 is executed. At step 210, the quoted instrument volume limits' effects on the maximum and minimum excursions are calculated. This is the subject of Figure 30. At step 211, it is asked whether notional position limits have been specified. If so, step 212 is executed. At step 212, the notional position limits' effects on the maximum and minimum excursions are calculated. This is the subject of Figure 31. At step 213, it is asked whether notional volume limits have been specified. If so, step 214 is executed. At step 214, the notional volume limits' effects on the maximum and minimum excursions are calculated. This is the subject of Figure 32. At step 215, it is asked whether position limits have been specified for the traded instrument L:Q. If so, step 216 is executed. At step 216, the traded instrument L:Q position limits' effects on the maximum and minimum excursions are calculated. This is the subject of Figure 33. At step 217, it is asked whether volume limits have been specified for the traded instrument L:Q. If so, step 218 is executed. At step 218, the traded instrument L:Q volume limits' effects on the maximum and minimum excursions are calculated. This is the subject of Figure 34.

Then step 219 is executed, where the maximum excursion is set to be equal to the maximum of 0 and the current value of the maximum excursion. This is done because we don't want to have a negative maximum excursion. At step 220, the minimum excursion is set to be the minimum of 0 and the current value

1 of the minimum excursion. This is done because we do not want
2 to have a positive minimum excursion. Then, the method ends
3 at step 221.

4
5 It is important to note that the order of taking into
6 account the effects of the eight types of specified input
7 credit limits is irrelevant, because each of the eight can
8 only constrict an excursion more, not expand it. Therefore,
9 the ultimate limit is the most restrictive one. All of the
10 eight trading limits described herein are recalculated after
11 each trade affecting that limit.

12 As used herein, a "trading limit" is something calculated
13 by computer 1, and a "credit limit" is something specified by
14 a guaranteeing agent 5.

15 Conventional mathematical shortcuts can be used to speed
16 the calculations without necessarily having to repeat all the
17 method steps in all but the first time a particular method is
18 executed. All of the steps of Fig. 26 get executed the first
19 time a method shown in Figures 27 through 34 is executed.

20
21 Figure 27 shows how computer 1 calculates the position
22 limit for the lot instrument, i.e., how computer 1 performs
23 step 204 of Figure 26. A position limit is a net limit in the
24 instrument being traded. The method starts at step 231. At
25 step 232, computer 1 retrieves the specified input maximum
26 position credit limit for instrument L, $PMAX(L)$, and the
27 specified input minimum position credit limit for instrument
28 L, $PMIN(L)$. Normally, $PMIN(L)$ is the negative of $PMAX(L)$, but

1 that doesn't necessarily have to be true. Also in step 232,
2 the net position, POS, is zeroed out.

3 In step 233, computer 1 looks for another unsettled flow
4 of instrument L in account A. "Another" is arbitrary. At
5 step 234, it is asked whether such another unsettled flow
6 exists. If not, control passes to step 238. If the answer is
7 "yes", step 235 is executed, wherein it is asked whether the
8 flow is to account A's borrower 2. A "flow" is a transfer of
9 a single instrument along a single edge 3. This is the same
10 as asking whether the flow is to other than a guaranteeing
11 agent 5, because the lender is the guaranteeing agent 5. If
12 the answer is yes, step 236 is executed, during which POS is
13 augmented by the flow amount, and control passes back to step
14 233. This inner loop 233-236 constitutes calculation of the
15 net position, and is performed for each Q matching that L.

16 If the answer to the question posed in step 235 is "no",
17 step 237 is executed, wherein POS is decremented by the flow
18 amount, and control is passed back to step 233. At step 238,
19 X is set to be equal to $PMAX(L)$ minus POS, and Y is set equal
20 to $PMIN(L)$ minus POS. X is the maximum excursion from this
21 flowchart and Y is the minimum excursion from this flowchart.
22 At step 239, the maximum excursion for the traded instrument
23 L:Q is set to be equal to the minimum of the current value of
24 this maximum excursion and X; and the minimum excursion for
25 the traded instrument L:Q is set to be equal to the maximum of
26 the minimum of the current value of the minimum excursion and
27
28

1 Y. In other words, the set of maximum and minimum excursions
2 is updated based upon the results of this flowchart. The
3 method ends at step 240.

4
5 Figure 28 illustrates how computer 1 calculates the
6 position limit for the quoted instrument, i.e., how computer 1
7 performs step 208 of Figure 26. Other than the fact that Q is
8 substituted for L, the method described in Figure 28 is
9 identical to that described in Figure 27, with one exception:
10 in step 259 (analogous to step 239 of Figure 27), we convert
11 from the quoted instrument to the lot instrument, because we
12 want everything expressed in terms of the lot instrument once
13 we get to the higher level flowchart (Fig. 26). Therefore, in
14 step 259, X and Y are each multiplied by a "fixed rate Q:L"
15 (exchange rate). This exchange rate is fixed for a certain
16 period of time, e.g., one hour or one day, and may be
17 different for different accounts at the same moment in time.

18
19 Figure 29 illustrates how computer 1 calculates the
20 volume limit for the lot instrument, i.e., how computer 1
21 performs step 206 of Figure 26. A volume limit is a gross
22 limit in the instrument being traded. The method starts at
23 step 271. In step 272, computer 1 retrieves the specified
24 input maximum permissible volume credit limit for instrument
25 L, VMAX(L); and clears a variable field VOL representing total
26 volume. In step 273, computer 1 looks for another unsettled
27 flow of instrument L in account A. "Another" is arbitrary.
28 At step 274, it is asked whether such another unsettled flow

1 has been found. If "yes", at step 275, VOL is augmented with
2 the flow amount. It doesn't matter whether the flow is in or
3 out to a particular node 2; it counts towards the volume limit
4 the same in each case.

5
6 Control is then passed back to step 273. If the answer
7 posed in step 274 is "no", step 276 is executed, wherein X is
8 set equal to $V_{MAX}(L)$ minus VOL, and Y is set equal to minus X,
9 because of the definition of "volume". Again, X and Y are the
10 partial limits as calculated by this particular flowchart.
11 Then in step 277, the maximum excursion is set equal to the
12 minimum of the previous value of the maximum excursion and X;
13 in the minimum excursion is set equal to the maximum of the
14 previous value of the minimum excursion and minus X. In other
15 words, the overall excursions are updated based upon the
16 results of this flowchart. The method then ends at step 278.

17
18 Figure 30 illustrates how computer 1 calculates the
19 volume limit for the quoted instrument, i.e., how computer 1
20 performs step 210 of Figure 26. Other than the fact that Q is
21 substituted for L, the method steps of Figure 30 are identical
22 to those of Figure 29, with one exception: in step 287
23 (analogous to step 277 of Figure 29), X and minus X are each
24 multiplied by "fixed rate Q:L" for the same reason that this
25 factor was introduced in Figure 28.

26
27 Figure 31 illustrates how computer 1 calculates the
28 notional position limit, i.e., how computer 1 performs step
212 of Figure 26. The notional position limit protects the

1 guaranteeing agent 5 against rate excursions aggregated over
2 the positions in all of the instruments. "Notional" means we
3 are changing the notation; the concept implies that there is a
4 conversion from one instrument to another, and that the
5 conversion is done at a certain rate that has been agreed
6 upon. The rate is set periodically, e.g., daily. This
7 conversion from one instrument to another is used to convert
8 all values into a single currency for the purpose of
9 aggregation into a single value.
10

11 The method commences at step 291. At step 292, computer
12 1 retrieves the maximum notional position credit limit PMAXN,
13 where N is the notional instrument, i.e., the instrument in
14 which the limit is presented. In step 292, the notional
15 position, NPOS, is also zeroed out. In step 293, computer 1
16 looks for another instrument C with flows in account A. C is
17 an index designating the instrument for which we are executing
18 the loop 293-301. The order of selecting the instruments is
19 immaterial. Step 294 asks whether such another instrument C
20 has been found. If not, control passes to step 302. If the
21 answer is yes, step 295 is executed, wherein the instrument
22 position, POS(C), is zeroed out. At step 296, computer 1
23 looks for another unsettled flow of instrument C in account A.
24

25 Step 297 asks whether such another unsettled flow has
26 been found. If not, control passes to step 301. If the
27 answer is "yes", step 298 is executed, where it is asked
28 whether the flow is to account A's borrower 2. If "yes",

1 POS(C) is augmented with the flow amount at step 299. If not,
2 POS(C) is decremented by the flow amount at step 300. In
3 either case, control is returned to step 296. Note that the
4 inner loop 296-300 is analogous to the loops in Figures 27 and
5 28. At step 301, NPOS is augmented by the absolute value of
6 POS(C) multiplied by "fixed rate C:N", which converts to the
7 notional instrument. The absolute value of POS(C) is used,
8 because a negative position presents the same risk to the
9 guaranteeing agent 5 as a positive position.
10

11 Before we describe step 302, let us define A and B, as
12 those terms are used in step 302. Note that "A" in step 302
13 is not the same as "account A". A is the position of L,
14 POS(L), multiplied by "fixed rate L:N", which converts this
15 position to the notional instrument. B is the position of Q,
16 POS(Q), multiplied by "fixed rate Q:N", which converts this to
17 the notional instrument. The positions of L and Q are as
18 calculated in the above loop 294-301; if L and Q were not
19 subject to these notional limits, then A and B would be 0.
20

21 In step 302, computer 1 finds the minimum and maximum
22 roots of $F(X)$, where $F(X)$ is defined in step 302. The term
23 "root" is that of conventional mathematical literature, i.e.,
24 a value of X that makes $F(X)$ equal to 0. Let us define E to
25 be equal to the absolute value of A plus B , plus $NPOS$, minus
26 the absolute value of A , minus the absolute value of B , minus
27 $PMAXN$. If E is greater than 0, then there are no roots. In
28 that eventuality, we set the maximum excursion of the traded

1 instrument L:Q, MAXEXC(L,Q), and the minimum excursion of the
2 traded instrument L:Q, MINEXC(L,Q), to be equal to 0. If E is
3 less than or equal to 0, the maximum root is the maximum of
4 minus A and B, minus E/2; and the minimum root is the minimum
5 of minus A and B, plus E/2. Now we are ready to go to step
6 303.
7

8 At step 303, the maximum excursion of the traded
9 instrument L:Q is set equal to the minimum of the previous
10 version of the maximum excursion of the traded instrument L:Q
11 and the maximum root multiplied by "fixed rate N:L", which
12 converts it to the lot instrument. Similarly, the minimum
13 excursion of the traded instrument L:Q is set equal to the
14 maximum of the previous version of the minimum excursion of
15 the traded instrument L:Q and the minimum root multiplied by
16 the same conversion factor, "fixed rate N:L". The method
17 terminates at step 304.
18

19 Figure 32 illustrates how computer 1 calculates the
20 notional volume limit, i.e., how computer 1 performs step 214
21 of Figure 26. The method starts at step 311. At step 312,
22 computer 1 retrieves the specified input maximum notional
23 volume credit limit, VMAXN. This is a limit across all
24 instruments in the account. At step 312, the total volume,
25 VOL, is also zeroed out. At step 313, computer 1 looks for
26 another unsettled flow of any instrument C in account A.
27 Again, "another" is arbitrary. At step 314, it is asked
28

1 whether such another unsettled flow has been found. If "yes",
2 step 315 is executed; if "no", step 316 is executed.

3
4 Let R be the conversion factor "fixed rate C:N", where C
5 is the instrument that we are looping through currently.
6 Then, step 315 sets VOL to be the previous VOL plus the
7 quantity R times the flow amount. Step 313 is then entered
8 into. At step 316, X is set equal to VMAXN minus VOL. Again,
9 X is the limit from just this flowchart. At step 317, the
10 maximum excursion of the traded instrument L:Q is set equal to
11 the minimum of the previous value of the maximum excursion of
12 the traded instrument L:Q and X times "fixed rate N:L", i.e.,
13 we are converting from the notional instrument to the lot
14 instrument. Similarly, the minimum excursion of the traded
15 instrument L:Q is set equal to the maximum of the previous
16 version of the minimum excursion of the traded instrument L:Q
17 and minus X times the same conversion factor. The method ends
18 at step 318.

19
20 Figure 33 illustrates how computer 1 calculates an
21 instrument position limit, i.e., how computer 1 performs step
22 216 of Figure 26. This type of position limit differs from
23 the previous position limit flowcharts (Figures 27 and 28) in
24 that the guaranteeing agent 5 is specifying that another agent
25 2 cannot trade any more than j L for Q, rather than the other
26 agent 2 can trade no more than jL or jQ. This type of input
27 credit limit is not as common as the ones described in Figures
28 27 and 28. If no agent 2 has specified this type of input

1 credit limit, this flowchart 33 does not have to be executed.
2 (Similarly, if no agent 2 has specified a certain other type
3 of input credit limit, the flowchart corresponding to that
4 credit limit does not have to be executed.) Both the L and
5 the Q have to match in order for this flowchart 33 to be
6 executed, unlike the flowcharts described in Figures 27 and
7 28.
8

9 The method starts at step 321. At step 322, computer 1
10 looks up the specified maximum position credit limit for the
11 traded instrument L:Q, $PMAX(L,Q)$, and the specified minimum
12 position credit limit for the traded instrument L:Q,
13 $PMIN(L,Q)$. In step 322, the total position, POS, is also
14 zeroed out. In step 323, computer 1 looks for another
15 unsettled flow pair with lot instrument L, quoted instrument
16 Q, and account A. Again, "another" is arbitrary. At step
17 324, it is asked whether such another unsettled flow pair has
18 been found. If "no", control passes to step 328. If "yes",
19 control passes to step 325, where it is asked whether the lot
20 instrument flows to account A's borrower 2. In other words,
21 the calculation is done in terms of the lot instrument to
22 begin with, so that we do not have to convert to the lot
23 instrument at the end of the calculation. If the answer to
24 this question is "yes", step 326 is executed, where POS is
25 incremented with the lot instrument flow amount. Control then
26 passes to step 323. If the answer to the question posed in
27 step 325 is "no", step 327 is executed, where POS is
28

1 decremented by the lot instrument flow amount. Again, control
2 then passes to step 323. At step 328, X is set equal to
3 $PMAX(L,Q)$ minus POS, and Y is set equal to $PMIN(L,Q)$ minus
4 POS. At step 329, the maximum excursion of the traded
5 instrument L:Q is set equal to the minimum of the previous
6 version of the maximum excursion of the traded instrument L:Q
7 and X; and the minimum excursion of the traded instrument L:Q
8 is set equal to the maximum of the previous value of the
9 minimum excursion of the traded instrument L:Q and Y. The
10 method ends at step 330.

12 Figure 34 illustrates how computer 1 calculates a traded
13 instrument volume limit, i.e., how computer 1 performs step
14 218 of Figure 26. This method is similar to the method
15 described in Figures 29 and 30, except the limit is on the
16 volume traded of L for Q, not a limit on the volume of L or Q
17 individually. The method starts at step 341. In step 342,
18 computer 1 retrieves the specified maximum volume input credit
19 limit for the traded instrument L:Q, $VMAX(L,Q)$. Also in step
20 342, the total volume VOL is zeroed out. In step 343,
21 computer 1 looks for another unsettled flow pair with lot
22 instrument L, quoted instrument Q, and account A. Again,
23 "another" is arbitrary.

25 At step 344, it is asked whether such another unsettled
26 flow pair has been found. If "no", control passes to step
27 346. If "yes", control passes to step 345, where VOL is
28 augmented by the lot instrument flow amount. The calculation

1 is done in the lot instrument, so that we do not have to
2 convert to the lot instrument at the end; and it makes the
3 calculation more stable, because we don't have to worry about
4 fluctuating rates. Control is then passed to step 343. At
5 step 346, X is set equal to $V_{MAX}(L,Q)$ minus VOL. At step 347,
6 the maximum excursion of the traded instrument L:Q is set
7 equal to the minimum of the previous version of the maximum
8 excursion of the traded instrument L:Q and X. Similarly, the
9 minimum excursion of the traded instrument L:Q is set equal to
10 the maximum of the previous value of the minimum excursion of
11 the traded instrument L:Q and minus X. The method stops at
12 step 348.
13

14 Figure 35 illustrates the reporting by computer 1 of
15 single-hop trades. This method is executed after a match has
16 been made, i.e., after a bid or offer has been taken by a
17 counterparty 2. The method of Figure 35 can be done either in
18 real time or in batch mode (i.e., combined with the reporting
19 of other trades). In Fig. 35, L is the lot instrument, Q is
20 the quoted instrument, B is the agent 2 who is buying L, S is
21 the agent 2 who is selling L, P is the trade price, F_L is the
22 amount of L bought and sold, F_Q is P times F_L , i.e., the
23 counter-amount in terms of instrument Q, and T is the
24 settlement date and time.
25

26 The method starts at step 351. At step 352, central
27 computer 1 issues an electronic deal ticket 353 to an auditor.
28 The auditor is a trusted third party, e.g., an accounting

1 firm. Ticket 353 has a plaintext portion and an encrypted
2 portion. The plaintext gives the ticket ID, and the time and
3 date that the ticket 353 is generated. The encrypted portion
4 states that agent B bought F_L for F_Q from agent S for
5 settlement at T. Deal ticket 353 is digitally signed by
6 central computer 1 for authentication purposes, and encrypted
7 by central computer 1 in a way that the auditor can decrypt
8 the message but central computer 1 cannot decrypt the message.
9 This is done for reasons of privacy, and can be accomplished
10 by computer 1 encrypting the message using the public key of
11 the auditor in a scheme using public key cryptography.

12
13 At step 354, computer 1 issues an "in" flow ticket 355 to
14 buyer B and to the auditor. Flow ticket 355 contains a
15 plaintext portion and an encrypted portion. The plaintext
16 gives the ticket ID, the time and date the ticket 355 is
17 generated, and the name of agent B. The encrypted portion
18 states that you, agent B, bought F_L for F_Q from counterparty S
19 for settlement at T. Ticket 355 is digitally signed by
20 computer 1 and encrypted in such a way that it may be
21 decrypted only by agent B and by the auditor, not by computer
22 1. Two different encryptions are done, one for agent B and
23 one for the auditor.
24

25 At step 356, computer 1 issues an "out" flow ticket 357
26 to seller S and to the auditor. Out flow ticket 357 contains
27 a plaintext portion and an encrypted portion. The plaintext
28 gives the ticket ID, the time and date of issuance, and the

1 name of agent S. The encrypted portion states that you, agent
2 S, sold F_L for F_Q to counterparty B for settlement at T.
3 Ticket 357 is digitally signed by computer 1 and encrypted
4 only to agent S and to the auditor, not to computer 1. Two
5 different encryptions are used, one to agent S and one to the
6 auditor.
7

8 Tickets 353, 355, and 357 can include the digital
9 identity of the individual within the agent 2 whose smartcard
10 was plugged into the agent's computer when the transaction was
11 made. The method ends at step 358.

12 Figure 36 illustrates how computer 1 electronically
13 reports a multi-hop deal. This method is performed after the
14 match has been made and can be done either in real time or in
15 batch mode. Agents B and S do not know each other, as they
16 know the identities of just their nearest neighboring agents
17 2. The notation for this flowchart is identical to that for
18 Figure 35, except that B is the ultimate buyer of L and S is
19 the ultimate seller of L.
20

21 The method begins at step 361. At step 362, computer 1
22 issues deal ticket 363 to the auditor. Ticket 363 contains a
23 plaintext portion and an encrypted portion. Ticket 363 is
24 digitally signed by computer 1 and encrypted only to the
25 auditor. The encrypted portion states that agent B bought F_L
26 for F_Q from agent S for settlement at T, and that the deal was
27 fulfilled by multiple direct trades in D, the directed deal
28 fulfillment graph, i.e., the type of graph that is illustrated

1 in Figure 11. In other words, the auditor knows every agent 2
2 in the chain.

3 At step 364, computer 1 looks for the next unprocessed
4 agent V in graph D. Again, "next" is arbitrary. At step 365,
5 it is asked whether such an unprocessed agent V has been
6 found. If not, the method stops at step 366. If the answer
7 is "yes", node loop 370 is entered into. For agent V, this
8 node loop examines the set E_V of directed edges 3 in D which
9 have agent V as either a source or destination. Each edge 3
10 has an amount F that is greater than zero and less than or
11 equal to F_L . Note that this verification process is for
12 illustration only; there would not be a match if these
13 constraints were not satisfied. At step 367, it is asked
14 whether agent V is the ultimate buyer B of the deal. If "no",
15 control is passed to step 368. If "yes", control is passed to
16 step 371.

17 At step 368, it is asked whether agent V is the ultimate
18 seller S of the deal. If "no", control is passed to step 369.
19 If "yes", control is passed to step 372. At step 369,
20 computer 1 concludes that agent V is an incidental participant
21 in the deal, i.e., a middleman 5. Control is then passed to
22 step 373, which verifies that the sum of the edge 3 amounts
23 having agent V as a source equals the sum of the edge amounts
24 3 having agent V as a destination. Sums are used because that
25 agent 5 could have several edges 3 in and out. Therefore, it
26 is known that agent V has no net market position change.
27
28

1 Control is then passed to step 376. At step 372, it is
2 verified that agent V is the source node 2 (as opposed to the
3 destination node) of all edges 3 in E_v . In step 375, it is
4 verified that edge 3 amounts in E_v sum to F_L , the net amount
5 sold. Control is then passed to step 376.
6

7 In step 371, it is verified that agent V is the
8 destination node 2 (as opposed to the source node) of all
9 edges 3 in E_v . At step 374, it is verified that edge 3
10 amounts in E_v sum to F_L , the net amount bought. Control is
11 then passed to step 376, where computer 1 looks for the next
12 unprocessed edge in E_v corresponding to account A. Steps 376-
13 382 constitute an edge loop. Account A is any account held by
14 or extended to counterparty X. Counterparty X is the
15 counterparty 2 to agent V for that edge 3. The edge 3 has to
16 have some amount F, where F is greater than 0 and less than or
17 equal to F_L , and an implicit counter-amount F times P;
18 otherwise, there would be no way to clear the trade. Again,
19 "next" in step 376 is arbitrary. Control is then passed to
20 step 382.
21

22 At step 382, it is asked whether such a next unprocessed
23 edge 3 has been found. If not, control is passed to step 364.
24 If "yes", control is passed to step 381, where it is asked
25 whether agent V is the destination node 2 for this edge 3. If
26 "yes", then step 380 is executed. If "no", then by
27 definition, agent V is the source node 2 for this edge 3, and
28

1 step 379 is executed. Control is passed to step 376 after
2 either of step 379 or 380 is executed.

3 At step 380, computer 1 reports an "in" flow ticket 377
4 to agent V, because the lot currency is flowing in to agent V.
5 Flow ticket 377 contains a plaintext portion and an encrypted
6 portion. The plaintext includes the ticket ID, the time and
7 date of issuance, and the name of agent V. The encrypted
8 portion states that you, agent V, bought F of L for F times P
9 of Q from counterparty X for settlement at T. In this case,
10 counterparty X is just the immediate neighbor 2 to agent V,
11 preserving anonymity. Ticket 377 is digitally signed by
12 computer 1 and encrypted by computer 1 only to agent V and to
13 the auditor, not to computer 1. Two encryptions are
14 performed, one to agent V and one to the auditor.
15

16 At step 379, computer 1 generates an "out" flow ticket
17 378 to agent V. Ticket 378 contains a plaintext portion and
18 an encrypted portion. The plaintext includes the ticket ID,
19 the time and date of issuance, and the name of agent V. The
20 encrypted portion states that you, agent V, sold F of L for F
21 times P of Q to counterparty X for settlement at T. Again,
22 counterparty X is just the immediate neighbor 2 to agent V,
23 preserving anonymity. Flow ticket 378 is digitally signed by
24 computer 1 and encrypted by computer 1 only to agent V and to
25 the auditor, not to computer 1. Two encryptions are
26 performed, one to agent V and one to the auditor.
27
28

1 Tickets 363, 377, and 378 can include the digital
2
3 identity of the individual within agent 2 whose smartcard was
4 plugged into the agent's terminal when the transaction was
5 made.

6 The above description is included to illustrate the
7 operation of the preferred embodiments and is not meant to
8 limit the scope of the invention. The scope of the invention
9 is to be limited only by the following claims. From the above
10 discussion, many variations will be apparent to one skilled in
11 the art that would yet be encompassed by the spirit and scope
12 of the present invention.

13 What is claimed is:
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